Pharmaceutical activities of Phytochemicals in Murraya spp. - a review

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ABSTRACT

Murraya is one of the 150 genera from the family Rutaceae. Of the 14 global species belonging to this genus, only three species i.e. Murraya koenigii, Murraya paniculata and Murraya exotica have been found in India. The plant Murraya paniculata is native to South-west Asia. The leaves have been reported to possess stimulant and astringent properties. The plant Murraya koengii is a tropical to sub-tropical tree. It is native to India and now widely distributed in most of Southern Asia. The plant has anti-inflammatory, anti-amnesic, anti-diabetic, anti-fungal, anti-bacterial, anti-helminthic and anti-cancer and anti-oxidative properties. The leaf, flower and fruit extracts of Murraya exotica have been reported to show anti-bacterial effect. The main categories of phytochemicals present in Murraya spp. include carbazole alkaloids, coumarins and flavonoids. Keeping this in mind an attempt has been made to review briefly the pharmaceutical activities of phytochemicals of Murraya spp. belonging to the family Rutaceae.

KEYWORDS: Murraya; Rutaceae; carbazole; coumarins; flavonoids.

1. INTRODUCTION

Plants, the green factories of nature possess a large number of chemical substances with varied therapeutic uses. They have been used as medicines, since ancient times. Medicinal plants are the main source of new pharmaceuticals and health care products (Vaghasiya et al., 2011). Keeping this in mind an attempt has been made to review briefly the pharmaceutical activities of phytochemicals of Murraya spp. belonging to the family Rutaceae. Murraya is one of the 150 genera from the family Rutaceae. The genus Murraya was named after John Andrew Murray, a Swedish botanist and a professor of Medicine and Botany, in the University of Gottingen. Of the 14 global species belonging to this genus, only three species i.e. Murraya koenigii, Murraya paniculata and Murraya exotica have been found in India.

The plant M. paniculata is native to South-West Asia. The leaves have been reported to possess stimulant and astringent properties (Parrotta, 2001) and are used in the treatment of diarrhea and dysentery. Murrayin, a glucoside from the plant is used to heal bruises and eruptions. The juice of the roots is used to relieve pain in kidney problems (Kirtikar and Basu., 1935; Ambasta, 1986). The plant M. koenigii is a tropical to sub-tropical tree. It is native to India and now widely distributed in most of Southern Asia. The plant has anti-inflammatory, anti-amnesic, anti-diabetic, anti-fungal, anti-bacterial, anti-helminthic and anti-cancer and anti-oxidative properties (Tachibana et al., 2003; Adebajo et al., 2006; Ningappa et al., 2008; Hema et al., 2011; Vohra and Gupta 2011).

M. exotica L. (commonly known as Chinese box or Jasmine orange) is an evergreen shrub, usually 2-3 m in height. Orange jasmine is native of continental tropical Asia (Matu, 2011). It is extensively grown as an ornamental plant and for fencing the gardens (Ghani, 1998). M. exotica L. is adapted to a wide range of conditions. It grows at an elevation of 1300 m above the sea level (Neal, 1965). The leaves of M. exotica L. have been reported to contain alkaloids (Desoky et al., 1992), coumarins (Ito and Furukawa, 1987; Barik and Kundu, 1987; Barik et al., 1983), flavonoids (Bishay et al., 1987), phytosterols (Desosky, 1995) and dipeptides (Ahmad and Begum, 1987). The leaf, flower and fruit extracts have been reported to show anti-bacterial effect against Candida albicans, Escherichia coli, Bacillus pyocyaneus, Staphylococcus aureus and Sarcina lutea (Sakhawat et al., 1998). Kong et al., (1985) reported the contraceptive properties of this plant. Yuehchukene, an alkaloid from this plant showed significant anti-implantation effects in female mice, when given orally or subcutaneously. Low dose of yuehchukene were reported to have anti-tumor effects (Leung et al., 2000). The sap squeezed from the leaves is used in diarrhea and dysentery. The roots possess anti-
pyretic activity. Murrangatin, a coumarin derived from the leaves show antithyroid property (Khare, 2007). The categories of phytochemicals reviewed in this article, include carbazole alkaloids, coumarins and flavonoids.

2. Traditional use
The people of Akole tehsil of Ahmednagar district located in Western Ghats of Maharashtra State used the fusion of root and bark powder of *M. paniculata* (L.) Jack. in milk along with turmeric orally in asthma (Khyade et al., 2010). Paste of dried bark of *M. paniculata* used as antivenom and sex stimulant by the rural communities in the district of Bankura and Purulia, West Bengal, India (Ghosh et al., 2013). *M. paniculata* (L.) Jack. stem bark is chewed at the side where the teeth pains as a cure for toothache (Rajan et al., 2001). The leaf paste of *M. paniculata* (L.) Jack is applied over the wounds by the Irula tribe of Hasanur Hills, Erode District, Tamil Nadu, India (Revathi and T. Parimalazhagan, 2010). Juice of tender leaves of *M. koenigii* (L.) Sprengel taken orally to arrest vomiting. Also used in stomach problems, by the Malayalis tribes in Pachamalai Hills (Bhaskar and Samant, 2012).

3. Alkaloids
Alkaloids are defined as basic (alkali-like), nitrogen-containing organic constituents that occur mainly in plants. Carbazole alkaloids are the main alkaloids present in *Murraya* spp. (Table 1).

a) Carbazole alkaloids:
Carbazole alkaloids contain the basic carbazole nucleus derived from an indole and isoprene units in which one of the isoprenes is cyclized back to the indole to form a benzene ring. These alkaloids occur in plants of the family Rutaceae. There are three basic groups of carbazole alkaloids (Gunatilaka, 1999) viz. the murrayanine or C13 group, heptaphylline-glycomaurral or C14 group and mahanimbine and related alkaloids or C23 group.

b) Isolation of carbazole alkaloids in *Murraya* spp.
Ganguly and Sarkar (1978) reported a new carbazole alkaloid, exozoline from the leaves of *M. exotica*. Ito *et al.* (1992) reported a new carbazole alkaloid, murrayamine-C, isolated from the fruits of *M. euchrestifolia*. The spectrometric methods were used to establish the structure of the carbazole alkaloid isolated. Ruangrungsi *et al.* (1990) isolated eight components, including three new carbazole alkaloids. 3-formyl-2, 7-dimethoxy carbazole, 7-methoxy-murrayacine, 3-formyl-2-methoxy carbazole or methylmukonal. These were isolated from the roots of *M. siamensis* and their structures were determined by spectroscopic techniques. From the eight components isolated, seven were carbazole alkaloids whereas one component was coumarin xanthoxyltein. A detailed 1H and 13C-NMR study of the seven carbazole was reported. Two novel cannabinol-skeletal carbazole alkaloids, murrayamine-O and murrayamine-P were isolated from acetone extract of the root barks of *M. euchrestifolia* (Wu *et al.*, 1995). These carbazole alkaloids were isolated from the more polar fractions of silica gel column by repeated preparative thin layer chromatography. The molecular formula for both the compounds was determined by high resolution mass spectrometry as C23, H27, NO3. The isolated compounds would be stereoisomer as suggested by their similarity in spectral data (IR, MS, and NMR).

Bringmann and Tasler (2001) for the first time reported the synthesis of the methylene-bismurrayafoline-A and chrestifoline-A. A potential novel type of natural product, a benzylcally connected trimer (methylene-bridged tricarbazole) was also identified. The yield of bismurrayafoline-A and chrestifoline-A was reported to be 19% and 70%, respectively. They also isolated murranol and koenoline, the carbazole alkaloids. All of these carbazole alkaloids were isolated from *M. euchrestifolia* and *M. koenigii*. A new binary carbazole, 8, 8“-biskoenigine, along with its monomer, koenigine, was isolated from the leaves of *M. koenigii* (Wang *et al.*, 2002). The compound 8, 8“-biskoenigine, was isolated as a brown gum. The carbazole alkaloid nature of the compound was elucidated by 1H and 13C NMR spectra. The UV (343, 301, 225 nm), 1H and 13C NMR spectra of 8, 8“-biskoenigine were similar to those of koenigine, supporting that 8, 8“-biskoenigine was a dimer of koenigine. Bonesi *et al.*, (2004) studied the photochemistry of two 2-acycloxycarbazole, 2-acteylcarbazole and 2-benzoyloxy carbazole, in the synthesis of carbazole alkaloids. They described the photo-fries rearrangement as a mild and clean one-pot for the preparation of an advanced intermediate precursor in the total synthesis of carbazole alkaloids.

Four carbazole alkaloids were isolated from the stem bark and roots of *M. koenigii* (Bakar *et al.*, 2007). The structures of the compounds isolated were established by infrared, mass spectrometry and nuclear magnetic resonance. The carbazole alkaloids isolated from the hexane and chloroform extract were identified as mahanimbine, girinimbine, murrayanine, murrayafoline-A. The leaves of *M. koenigii* (Linn) Spreng, were found to contain a new carbazole alkaloid, murrayakoeninol (Chakraborty *et al.*, 2009). Mahanimbine, koenimbine, O-methylmurrayamine-A and murrayazoline, the known carbazole alkaloids were also isolated from the leaves and girinimbine was isolated from the bark. The structure of murrayakoeninol was elucidated by 2-D NMR spectral analysis and chemical reactions.

Murranimbine, a naturally occurring dimeric carbazole alkaloid was synthesized in one step by the application of Lewis acid (BF3·Et2O)
and its monomer girinimbine. It was isolated from the root bark of *M. euchrestifolia* (Chakraborty and Mukhopadhyay, 2010). Following the same procedure, they also synthesized a new dimer of koenidine. The structures of the isolated dimer carbazole alkaloid were determined by detailed spectral analysis. Nishiyama *et al.* (2011) developed a new methodology for the synthesis of carbazole-1, 4-quinones using a tandem ring-closing metathesis (RCM)-oxidation reaction. This new tandem reaction was applied for the synthesis of murrayquinone-A in the four steps (42.5% yield). Many functionalized carbocycles were constructed by using ring-closing metathesis (RCM) reaction by Grubb’s group.

c) **Bioactivities of carbazole alkaloids in* *Murraya* *spp.**

Unny *et al.* (2003) reported that the roots of both *M. exotica* L. and *M. paniculata* have contraceptive properties. 8, 10'-[3, 3', 11, 11'-tetrahydro-9, 9'-dihydroxy-3, 3', 5, 8'-tetramethyl-3, 3'-bis-(4-methyl-3-pentenyl)] bispyrano[3, 2-a] carbazole, a new carbazole alkaloid was isolated from the CH$_2$Cl$_2$ extract of *M. koenigii* together with six known carbazole alkaloids, koenimbine, O-methylmurrayamine-A, O-methyl-mahanine, isomahanine, bismahanine, and bispyrayafoline (Tachibana *et al.*, 2003). The antioxidative properties of the isolated carbazole alkaloids were evaluated on the basis of the oil stability index (OSI) and 1, 1-diphenyl-2-picrylhydrazl (DPPH) radical scavenging assay. The reaction rate of carbazole with free hydroxyl groups was considered to be faster than those without free hydroxyl group. The dimeric carbazoles showed high DPPH radical scavenging activity than the monomeric carbazole alkaloids except the 8,

**Table 1: Various carbazole alkaloids in *Murraya* *spp.***

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Alkaloids</th>
<th>Chemical Structure</th>
<th>Source plant</th>
<th>References</th>
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<tbody>
<tr>
<td></td>
<td>Mahanimbine (R$_1$: H, R$_2$: CH$_3$, R$_3$:-(CH$_2$)$_2$CH=C(CH$_3$)$_2$)</td>
<td><img src="image2" alt="Chemical Structure" /></td>
<td></td>
<td></td>
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<td></td>
<td>Girinimbine (R$_1$: H, R$_2$:H)</td>
<td><img src="image3" alt="Chemical Structure" /></td>
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<tr>
<td></td>
<td>Murrayanine (R$_1$: CHO, R$_2$: OCH$_3$)</td>
<td><img src="image4" alt="Chemical Structure" /></td>
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<tr>
<td></td>
<td>Murrayafoline-A (R$_1$: CH$_3$, R$_2$: OCH$_3$)</td>
<td><img src="image5" alt="Chemical Structure" /></td>
<td></td>
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<td></td>
<td>Bismurrayafoline-A (X=H)</td>
<td><img src="image7" alt="Chemical Structure" /></td>
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<td></td>
<td>Chrestifoline-A.</td>
<td><img src="image8" alt="Chemical Structure" /></td>
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<td>S. No.</td>
<td>Alkaloids</td>
<td>Chemical Structure</td>
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<td>3.</td>
<td>Murrinimbine</td>
<td><img src="image" alt="Chemical Structure" /></td>
<td><em>Murraya euchrestifolia</em> and <em>Murraya koenigii.</em></td>
<td>Bringmann and Tasler (2001)</td>
</tr>
<tr>
<td>4.</td>
<td>Murrayamine- O and murrayamine- P</td>
<td><img src="image" alt="Chemical Structure" /></td>
<td><em>Murraya euchrestifolia</em></td>
<td>Wu et al. (1995)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Murrayamine- O (R$_1$: CH$_3$, R$_2$: OH) Murrayamine- P (R$_1$: OH, R$_2$: CH$_3$)</td>
<td></td>
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<td>5.</td>
<td>3-formyl-2, 7-dimethoxycarbazole, 7-methoxy murrayacine, 3-formyl-2-methoxycarbazole or methylmukonal</td>
<td><img src="image" alt="Chemical Structure" /></td>
<td><em>Murraya siamensis</em></td>
<td>Ruangrungsi et al. (1990)</td>
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<td></td>
<td></td>
<td>3-formyl-2, 7-dimethoxycarbazole (R$_1$: OMe, R$_2$: Me) 7-methoxy murrayacine</td>
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<td>6.</td>
<td>9-carbethoxy-3-methylcarbazole and 9-formyl-3-methylcarbazole</td>
<td><img src="image" alt="Chemical Structure" /></td>
<td><em>Murraya koenigii</em></td>
<td>Chakrabarty et al. (1997)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9-carbethoxy-3-methylcarbazole 9-formyl-3-methylcarbazole</td>
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</table>
Adebajo et al. (2006) observed the toxicological and biochemical effects of methanolic extracts of leaves of *M. koenigii* on rats. The extract was found to be moderately toxic to rats and had appreciable effect on liver and kidney at higher doses leading to liver inflammation. Acute doses (=500 mg/kg) were found to significantly reduce serum globulin, albumin, urea, glucose, total protein, aspartate transaminase, and increased cholesterol and alanine transaminase indicating hepatic injury. This activity of the leaf extract was due to the presence of carbazole alkaloids. Girinimbine and girinimbilol with IC<sub>50</sub> values of 1.08 and 1.20 µg/ml were found to be the most active. Rao et al. (2007) evaluated the antioxidative activity of oleoresin from *M. koenigii* (curry leaves), using a β-carotene-linoleic acid model system. This oleoresin showed maximum activity of 83.2% at 100 ppm in comparison to butylated hydroxyl anisole (BHA) which exhibited 90.2% activity at the same concentration. The methanol and water extracts showed activities of 16.7% and 11.3%, respectively, at the same concentration, whereas the volatile oil showed negligible (<10%) activity. The oleoresin was also fractionated on a silica gel column to obtain five compounds. Koenigine showed a high degree of radical scavenging activity. Bioactivities of various carbazole alkaloids present in *Murraya* spp are tabulated in table 3.

1. Coumarins
Coumarins belong to benzopyrones group of compounds (Keating and Konnedy, 1997). They may occur either free or in combination with sugar glucose (coumarin glycosides).

a) Isolation of coumarins in *Murraya* spp.
Table 2 shows various types of coumarins in *Murraya* spp. Chakraborty and Chowdhury (1967) reported a new coumarin, mexoticin from *M. exotica* L. Ramsted et al. (1968) identified a new coumarin, coumurrayin from *M. paniculata* (L.) Jack. Talapatra et al. (1973) isolated a new monomeric coumarin from the leaves of *M. elongata*. The chemical and spectroscopic methods confirmed that the identified compound had its chemical correlation with phebalosin. The compound was identified as murrangatin. Raj et al. (1976) isolated and identified coumarins: murralongin, murrangatin, meranzin hydrate in *M. paniculata*. Coumurrayin and 5, 7-dehydroxy-8-(3'-methyl-2'-oxobutyl) coumarin were reported from the ethanolic extract of the fruits of *M. omphalocarpa* (Wu et al., 1980). The compounds were characterized by using the spectral data. A new antibiotic dicoumarin, mexolide was reported from *M. exotica* Linn (Chakraborty et al., 1980). The mexolide was found to have an unusual cyclohexane system. Wu (1981) isolated omphurin, a new coumarin from the hexane extract of the leaves of *M. omphalocarpa*. The chemical and spectral analysis confirmed the structure of omphurin as 5,7-dimethoxy-8-(2'-hydroxy-3'-methyl-3'-butenyl) coumarin.

Barik et al. (1983) first time reported auraptenol and merazin hydrate in *M. exotica*. This was first report of isolation of auraptenol from a natural source. The spectral analysis using 13C NMR was also studied. The absolute configuration of auraptenol was found to possess S configuration at C-2'. Barik et al. (1983) isolated murrayatin, a coumarin from the leaves of *M. exotica*. The spectral analysis and chemical transformation established the structure of murrayatin as 7-methoxy-8-(2'-isovaleryloxy-3'-hydroxy-3'-methylbutyl) coumarin. Wickramarante et al. (1984) reported murruglein, a trioxynogenated C-8 prenylated coumarin from the leaves of *M. gleinei*. The structure was established as 5, 6, 7-trimethoxy-8-(2',3'-dihydroxyisopenteny) coumarin. The laevorotatory form of mexitoxin, sibiricin and phebalosin were also isolated from the leaves, together with other coumarins such as meranzin, murrangatin and scopoletin. Gleine and gleinadiene, 5, 7-dimethoxy coumarins were reported from the roots of *M. gleinei* (Kumar et al., 1987). The compounds were assigned the structure as 5, 7-dimethoxy-8-(3'-methylbutan-1', 3'-diynyl) coumarin and 5, 7-dimethoxy-8-(3'-methylbut-1'-enyl) coumarin. Eleven other coumarins, thirteen sesquiterpenoids and six fatty acids were also isolated.

A cinnamic acid derivative, marraxonin and a new coumarin, murraxocin isolated from the leaves of *M. exotica* (Barik and Kundu, 1987). The chemical reaction characterized the compound murraxocin as 7-methoxy-3-{1-[ethoxy-2'- hydroxy-3'-methyl-but-3'-enyl]} coumarin. Wu (1988) isolated two new coumarins from the leaves of *M. paniculata* var. *omphalocarpa*. The spectroscopic methods elucidated the structures of the two new coumarins. They were identified as murrayanone and murraculatin. Seven known coumarins were also isolated. Paniculindines A, B, C, three new 3-prenylindoles were isolated from the root bark of *M. paniculata* together with known coumarins, murralangin and osthol (Kinoshita et al., 1989). Based on the spectroscopic and chemical evidence, their structures were elucidated as methyl 2-(R)-methyl-4-(3-indolyl)-butyrate, 2-(R)-methyl-4-(1-methoxy-3-indolyl)-1-butanol and 2-(R)-methyl-4-(3-indolyl)-1-butanol, respectively. Wu et al. (1989) reported four new coumarins, omphalocarpin, (-)-murracarpin, murrayacarpin-A and murrayacarpin-B from the flowers of *M. paniculata*. Along with the new coumarins, the known coumarins, scopolin, scopolitin, 5, 7-dimethoxy-8-(3'-methyl-2'-oxobutyl) coumarin, (±)-murracarpin and mupanidin were also
isolated. The chemical transformation and spectral analysis was used for the elucidation of the structures of the isolated coumarins.

Kinoshita et al. (1996) reported a new C-8 prenylated 5,7-dimethoxy-coumarin, omphamurrayone from the acetone extract of dried leaves of *M. paniculata* var. *omphalocarpa*. The spectral data elucidated its structure as 5,7-dimethoxy-8-(3-methyl-1-O-isovaleryl-2-oxobutyl)-coumarin. Besides this, eight other coumarins, murralongin, isomurralonginol isovalerate, murrangatin, minumicrolin (murpanidin), coumurrayin, toddalenone, aurapten and toddasin were also reported. Aurapten and toddasin were found to occur for the first time in *Murraya* spp. Attar-ur-Rahman et al. (1997) reported two new natural products and two known compounds, isolated from the methanolic extracts of the leaves of *M. paniculata* through column chromatography and TLC. The two new products were identified as methyl 2-methoxy-5-hydroxycinnamate and 8-(2'-oxo-3'-methyl)butoxy-7-methoxycoumarin. Methyl 2, 5-dihydroxy-cinnamate and murrayatin, the two known compounds were for the first time isolated from this plant. The compound methyl 2-methoxy-5-hydroxycinnamate, with molecular formula C_{11}H_{12}O_{4} showed UV absorption maxima at 218, 296 and 324 nm indicating the presence of a cinnamate nucleus. The compound 8-(2'-oxo-3'-methyl)-butoxy-7-methoxycoumarin, with molecular formula C_{12}H_{16}O_{5} isolated as an amorphous solid, showed UV absorptions at 256 and 321 nm.

Negi et al. (2005) reported two new coumarins, bismurrangatin and murramarin from the vegetative branches of *M. exotica*. The structures of the isolated coumarins were elucidated by spectroscopic methods, especially 2-D NMR. Bismurrangatin (molecular formula C_{30}H_{30}O_{9}) was isolated as colourless oil. The structure of bismurrangatin was found to be composed of two 7-methoxy-8-(1, 2-dihydroxy-3-methyl-3-butenyl) coumarins nuclei. Murramarin (molecular formula C_{32}H_{34}O_{10}) a colourless oil was found to be a rare type of biscoumarin which connected two coumarin moieties by orthoester structure, but did not contain a furanocoumarin moiety. A new coumarin derivative, paniculacin was isolated from the ethyl acetate soluble fraction of the ethanolic extract of *M. paniculata* (Saeed et al., 2011). Other compounds such as umbelliferone, scopoletin, 4-hydroxybenzoic acid, trans-cinnamic acid, and β-sitosterol were also reported from this species. The spectral analysis was used for the elucidation of the structures of the isolated compounds.

### Table 2: Various coumarins in *Murraya* spp.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Coumarin</th>
<th>Chemical structure</th>
<th>Source plant</th>
<th>References</th>
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<tr>
<td>1.</td>
<td>Bismurrangatin, murramarin</td>
<td><img src="image" alt="Bismurrangatin" /></td>
<td><em>Murraya exotica</em></td>
<td>Negi et al. (2005)</td>
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<td>2.</td>
<td>2-methoxy-5-hydroxycinnamate and 8-(2'-oxo-3'-methyl) butoxy-7-methoxycoumarin Methyl 2, 5-dihydroxy-cinnamate and murrayatin</td>
<td><img src="image" alt="Murramarin" /></td>
<td><em>Murraya paniculata</em></td>
<td>Attar-ur-Rahman et al. (1997)</td>
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<tr>
<td>S. No.</td>
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<td>Chemical structure</td>
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<tr>
<td>3.</td>
<td>Paniculacin</td>
<td><img src="image" alt="Chemical structure" /> Methyl 2, 5- dihydroxy-cinnamate (R: H) 8- (2' - oxo- 3'- methyl) butoxy- 7- methoxycoumarin.</td>
<td><em>Murraya paniculata</em></td>
<td>Saeed et al. (2011)</td>
</tr>
<tr>
<td>4.</td>
<td>Omphamurrayone</td>
<td><img src="image" alt="Chemical structure" /> Murrayatin</td>
<td><em>Murraya paniculata var. omphalocarpa</em></td>
<td>Kinoshita et al. (1996)</td>
</tr>
</tbody>
</table>
S. No. | Coumarin | Chemical structure | Source plant | References |
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**b) Bioactivities of coumarins in *Murraya* spp.**

Coumarin related compounds, isolated from *M. paniculata* were found to act as plant growth inhibitors (Jiwajinda *et al.*, 2000). Five 7-methoxycoumarins and one 5,7-dimethoxycoumarin were reported to show this activity. A new natural compound, murranganon senecioate was also reported in *M. paniculata*. The extracts from *M. paniculata* exhibited 82% inhibition. The plant growth inhibitory effects were evaluated by cucumber and rice seedling tests. The tested compounds were found to be ineffective both on the hypocotyl growth of cucumber and the root growth of the rice seedlings. Coumarins were found to respond more significantly to the 2nd leaf sheath elongation of the rice seedlings (IC$_{50} = 0.63$ mM). Minumicrolin with IC$_{50} > 2.0$ mM was found to be a potent growth inhibitor against the 2nd leaf sheath elongation of the rice seedlings.

Chen *et al.* (2003) examined the bioactivity of the coumarins isolated from the leaves of *M. omphalocarpa*. Eight coumarins, omphalocarpinol, 5,7-dimethoxy-8-(3'-methyl-2'oxobutyl) coumarin, murrionalin, murrayanone, omphamurin, murrageleinin, mexoticin, and murrangatin were isolated from the leaves. The spectroscopic techniques were used to elucidate the structures of the isolated compounds. The compounds omphalocarpinol, 5,7-dimethoxy-8-(3'-methyl-2'oxobutyl) coumarin and omphamurin were found to exhibit sig-
### Table 3: Bioactivities of phytochemicals of *Murraya* spp.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Plant</th>
<th>Active compound</th>
<th>Dose</th>
<th>Result</th>
<th>Reference</th>
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</thead>
<tbody>
<tr>
<td>Cytotoxic</td>
<td>Root bark of <em>M. koenigii</em></td>
<td>Koenoline</td>
<td>KB cell culture test system.</td>
<td>Fiebig et al., 1985</td>
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<td></td>
<td>Leaves of <em>M. echrestifolia</em></td>
<td>Murrayamine-A and (+)-mahanine</td>
<td>Against both mouse melanoma B16 and adriamcin-resistant p388 mouse leukemia cell lines.</td>
<td>Wu, 1991</td>
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<td>Chloroform extract of the roots of <em>M. koenigii</em></td>
<td>9-formyl-3-methylcarbazole</td>
<td>SK-MEL-5 and Colo-205 cell lines; HCT-8, KB, and A-549 tumor cell lines</td>
<td>Chakrabarty et al., 1997</td>
<td></td>
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<tr>
<td></td>
<td>Root bark of <em>M. euchrestifolia</em></td>
<td>Murrayquinone-A and murrayafoline-A</td>
<td>ED&lt;sub&gt;50&lt;/sub&gt; values of 2.58 and 3.85 µg/ml (murrayquinone-A)ED&lt;sub&gt;50&lt;/sub&gt; values ranging from 5.31 to 7.52 µg/ml (murrayafoline-A)</td>
<td>Itoigawa et al., 2000</td>
<td></td>
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<tr>
<td></td>
<td><em>M. koenigii</em></td>
<td>Mahanine, pyrayafoline-D and murrafoline-I</td>
<td>HL-60 cells</td>
<td></td>
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<tr>
<td>Antiimplantation</td>
<td>Roots of <em>M. exotica</em> and <em>M. paniculata</em></td>
<td>Mahanimbine (50 and 100 mg/kg)</td>
<td>Streptozotocin (45 mg/kg)- induced diabetic rats</td>
<td>Kong et al., 1985; 1986</td>
<td></td>
</tr>
<tr>
<td>Anti-inflammatory</td>
<td>Acetone extract of the fresh leaves of <em>M. koenigii</em></td>
<td>Murrayanol</td>
<td>Against hPGHS-2</td>
<td>Ramsewak et al., 1999</td>
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</tr>
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<td>Antosteoporotic</td>
<td>Sachet bark of <em>M. koenigii</em></td>
<td>Murrayanine and 8, 8'-biskoenigine</td>
<td>MIC in the range of 3.13-100 µg/ml</td>
<td>Wang et al., 2003</td>
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<tr>
<td>Antimicrobial</td>
<td>Seeds of <em>M. koenigii</em></td>
<td>Kurrram and koenimine</td>
<td>IC&lt;sub&gt;50&lt;/sub&gt; of 109 µg/ml against hPGHS-1 and an IC&lt;sub&gt;50&lt;/sub&gt; of 218 µg/ml</td>
<td>Rahman and Gray, 2005</td>
<td></td>
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<tr>
<td>Antidiarrhoeal</td>
<td>Leaves of <em>M. koenigii</em></td>
<td>Kurrayam and koenimbine</td>
<td>CAS-oil induced diarrhea and PGE&lt;sub&gt;2&lt;/sub&gt;-induced enteropooling in rats</td>
<td>Mandal et al., 2010</td>
<td></td>
</tr>
<tr>
<td>Anti-hyperglycemic and anti-lipidemic</td>
<td><em>M. koenigii</em> leaves</td>
<td>Mahanimbine (50 and 100 mg/kg)</td>
<td>The elevated fasting blood sugar, triglycerides, low density lipoprotein, very low density lipoprotein levels were reduced and high density lipoprotein level was increased</td>
<td>Kumar et al., 2010</td>
<td></td>
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<tr>
<td>Antitumor</td>
<td>Leaves of <em>M. siamensis</em></td>
<td>Murrayacoumarin A, 5-geranyoxy-7-hydroxyxocoumarin, 7-geranyoxy-6-methoxycoumarin</td>
<td>In vitro assay of TPA (12-O-tetradecanoylphorbol-13-acetate) induced EBV-EA (Epstein-Barr virus early antigen) activation in Raji cells.</td>
<td>Ito et al., 2005</td>
<td></td>
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<tr>
<td>Antidote activity against snake venom</td>
<td>Aerial parts of <em>M. alternans</em></td>
<td>(±)-Alemannian, a dihydrofuranocoumarin</td>
<td>Significant decrease in acetic acid-induced writhing response; increased in hot-plate latency, but suppressed xylene induced ear swelling and the carrageenan induced paw edema effectively</td>
<td>Min et al., 2007</td>
<td></td>
</tr>
<tr>
<td>Anti-inflammatory and antinociceptive activity</td>
<td>Ethanolic extract of <em>M. exotica</em></td>
<td>Murracarpin</td>
<td>The methods of acetic acid-induced writhing response and hot-plate latent pain response test were employed to evaluate the antinociceptive activities Whereas carrageenan induced hind paw edema, xylene induced ear edema, and a ratknee osteoarthritis model were used to measure the anti-inflammatory activities.</td>
<td>Wu et al., 2010</td>
<td></td>
</tr>
<tr>
<td>Oxidative stress control</td>
<td>Leaves of <em>M. koenigii</em></td>
<td>In vitro assessment was done on erythrocyte membrane of human volunteer while <em>in vivo</em> assessment was on aged human</td>
<td>Significant decrease in lipid peroxidation in plasma and erythrocytes, significant elevation in the levels of non enzymatic antioxidants (β-carotene, vitamin A, C &amp; E) in serum and</td>
<td>Andallu et al., 2011</td>
<td></td>
</tr>
<tr>
<td>Activity</td>
<td>Plant</td>
<td>Active compound</td>
<td>Dose</td>
<td>Result</td>
<td>Reference</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
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<tr>
<td>Antioxidant defense system and ultrastructural changes of pancreatic ß-cells</td>
<td>M. koenigii leaves</td>
<td>Diabetes in rats.</td>
<td>volunteers</td>
<td>significant decrease in the activity of catalase, elevated activities of superoxide dismutase and glutathione-s-transferase and raised reduced glutathione (GSH) in erythrocytes.</td>
<td>Arulselvan and Subramanian, 2007</td>
</tr>
<tr>
<td>Antinociceptive activity</td>
<td>Ethanol extract of leaves of M. paniculata (L.) Jack</td>
<td>Dose of 250 and 500 mg/kg of body weight</td>
<td>Acetic acid induced writhing model in mice</td>
<td>The extract was found to produce 26.67 and 66.67% writhing inhibition in test animals.</td>
<td>Sharkar et al., 2009</td>
</tr>
<tr>
<td>Diabetes</td>
<td>Ethanol extract of the leaves of M. koenigii</td>
<td>Streptozotocin induced diabetic rats</td>
<td>Diabetes-induced renal damage in vivo in diabetic rats</td>
<td>The extract decreased the blood glucose level in a dose dependent manner and also decreased the level of Thiobarbituric Acid Reactive Substances (TBARS) by inhibiting the lipid peroxidation formation.</td>
<td>Tembhurne and Sakarkar, 2010</td>
</tr>
<tr>
<td>Antioxidant defense system and ultrastructural changes of pancreatic ß-cells</td>
<td>Aqueous extract (AQ) the leaves of M. koenigii (Linn.)</td>
<td>Diabetes-induced renal damage in vivo in diabetic rats</td>
<td>Toxicity test</td>
<td>Significant dose dependent decrease was found in serum urea and creatinine levels, and also there was marked increase in the levels of plasma antioxidant capacity.</td>
<td>Yankuzo et al., 2011</td>
</tr>
<tr>
<td>Antiobesity effects</td>
<td>Water and ethanolic extracts of M. paniculata</td>
<td>LC₅₀ (ppm) of water and ethanolic extract was found to be 212.26, 442.83, respectively. 100 ppm of water extract showed 25.66% inhibition effect on the pancreatic lipase activity.</td>
<td>300mg/kg was administrated orally to normal and STZ (streptozotocin) induced severe diabetic rats for 1 month.</td>
<td>SGOT (serum glutamate oxaloacetate transaminase) and SGPT (serum glutamate pyruvate transaminase) levels were decreased by 21.7 and 25.0% in the normal rats, and by 36.7 and 32.2% in diabetic rats. There was decrease in the serum creatinine levels by 17.75 and 18.2%, in normal as well as in the diabetic animals, respectively. Also, 75% decrease in urine sugar was seen in treated diabetic rats. In the case of treated normal as well as diabetic rats, a fall of 19.2 and 30.8% in TC (total cholesterol) and 22.97 and 37.1% in TG (triglyceride) levels was also observed. After 4h of oral administration of 300 mg/kg, the fall of 14.68% in normal and 27.96% in mild diabetic was seen. Marked improvement in glucose tolerance of 46.25% in sub-diabetic (AR) and 38.5% in mild diabetic rabbits in glucose tolerance test was observed after 2 h.</td>
<td>Kesari et al., 2005</td>
</tr>
<tr>
<td>Glycemic and lipidemic effect</td>
<td>Aqueous leaves extract of M. koenigii.</td>
<td>Standard hypoglycemic drug, tolbutamide.</td>
<td>200, 300 and 400 mg/kg in normal as well as in diabetic rabbits</td>
<td>After 4h of oral administration of 300 mg/kg, the fall of 14.68% in normal and 27.96% in mild diabetic was seen. Marked improvement in glucose tolerance of 46.25% in sub-diabetic (AR) and 38.5% in mild diabetic rabbits in glucose tolerance test was observed after 2 h.</td>
<td>Kesari et al., 2005</td>
</tr>
<tr>
<td>Hypoglycemic effects</td>
<td>Aqueous extract of M. koenigii</td>
<td>5, 10 and 15% concentration</td>
<td>Diabetic rats</td>
<td>Reduction in blood sugar by 13.1, 16.3 and 21.4% (NS, P&lt;0.05 and 0.005) and 3.2, 5.58, 8.21% (NS) in mild and moderate diabetic rats, respectively; whereas negligible reduction in blood glucose was found in normal rats.</td>
<td>Yadav et al., 2002</td>
</tr>
<tr>
<td>Hypoglycemic and antihyperglycemic activity</td>
<td>Leaves of M. koenigii</td>
<td>10, 20 and 30 mg/kg</td>
<td>Intraperitoneal injection of scopolamine or diazepam, was used to induce amnesia in mice.</td>
<td>The memory in young and aged mice was significantly improved, when administered 15 days. There was significant reduction in the brain cholinesterase activity. IC₅₀ value of MKA against BACE1 (Beta-secretase 1) was 1.71 g/mL.</td>
<td>Mani et al., 2012</td>
</tr>
</tbody>
</table>

**Note:** The table above includes a summary of the effects observed in different studies on the plant M. koenigii and its extracts. The effects are categorized into antioxidant defense, antinociceptive activity, antiobesity effects, glycemic and lipidemic effect, hypoglycemic effects, hypoglycemic and antihyperglycemic activity, and management of Alzheimer's disease and dementia. The table lists the plant species, the type of extract or compound used, the dose administered, the result observed, and the reference for each study.
The patients (aged >50 years) acetate (MKE) extracts for 12 weeks. Birari

| Table 3 shows various types of flavonoids in Murraya spp. | Bioactivities of various carbazole alkaloids present in Murraya spp. are tabulated in table 3. |

5. Flavonoids

Flavonoids are polyphenolic compounds that occur as a major constituent in foods of plant origin (Grun et al., 2008).

a) Isolation of flavonoids in Murraya spp.

Table 3 shows various types of flavonoids in Murraya spp. de Silva et al. (1980) isolated 3',4',5',7', 8-hexamethoxyflavone and 3, 3', 4', 5', 7, 8-heptamethoxyflavone from the Sri Lankan M. paniculata. Wu et al. (1980) reported a new flavonol, murrayanol from the ethanolic extract of the fruits of M. omphalocarpa. The flavonol isolated was characterized as 5, 4'-dihydroxy-3, 6, 7, 3', 5'-pentamethoxyflavone. Wu et al. (1994) isolated and characterized a naturally occurring flavonoid, 3, 5, 7, 3', 4', 5'-hexamethoxyflavone. excellent hepatoprotective activity. Kinoshita and Firman (1996) reported eight highly oxygenated flavones, including one new compound, from the chloroform extract of M. paniculata. On the basis of chemical and spectroscopic studies, the new compound was elucidated as 5, 3', 5'-trihydroxy-6, 7, 4'-trimethoxyflavone. The other compounds were identified as 5-hydroxyl-6, 7, 8, 3', 4', 5'-pentamethoxyflavone (gardenin C), 6, 7, 8, 4'-tetramethoxy-5, 3', 5'-trihydroxyflavone (gardenin E), 5- hydroxyl-6, 7, 8, 3', 4', 5'-pentamethoxyflavone (5-O-desmethylnobiletin), 6, 7, 8, 3', 5', 7, 8-hexamethoxyflavone, 5-hydroxyl-6, 7, 3', 4', 5'-pentamethoxyflavone (umhergerin), 5, 3'-dihydroxy-6, 7, 4', 5'-tetramethoxyflavone.

Kinoshita and Firman (1997) reported seven flavonoids, including one new flavonol from the chloroform extract of M. paniculata. The new flavonol was identified as 3-hydroxy-5, 7, 3', 4', 5'-pentamethoxyflavone. A methylated flavone and its corresponding chalcone isomer, 2-(S)-5, 7, 3', 4', 5'-pentamethoxyflavone and 2'-hydroxy-3, 4, 5, 4'-pentamethoxychalcone, respectively, were also identified. Lapick et al. (2004) reported isolavonoids in the Rutaceae family, including M. paniculata. The compounds with immunoreactivity similar to isoflavonoids were detected from the ethanolic extract of the leaves of M. paniculata Jack. The immunoreactive isoflavonoids were identified by using HPLC-MS. Ferracin et al. (1998) reported nine flavonoids from the peel and pulp of the fresh ripe fruits of M. paniculata. Six flavonoids isolated from the dichloromethane extract of the peel of M. paniculata were identified as 5, 7, 3', 4', 5'-

pentamethoxyflavone, 5, 6, 7, 3', 4', 5'-hexamethoxyflavone, 3, 5, 7, 8, 3', 4', 5'-heptamethoxyflavone, 5, 7, 8, 3', 4', 5'-hexamethoxyflavone, 5-hydroxy-3, 7, 8, 3', 4', 5'-hexamethoxyflavone, 8-hydroxy-3, 7, 8, 3', 4', 5'-hexamethoxyflavone. Three flavonols isolated from the hexane-soluble fraction of the hydromethanolic extract of the pulp of *M. paniculata* were identified as 5-hydroxy-3, 7, 8, 3', 4'-pentamethoxyflavone, 3, 5, 6, 7, 3', 4', 5'-heptamethoxyflavone.

### Table 4: Various flavonoids in *Murraya* spp.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Flavonoids</th>
<th>Chemical Structure</th>
<th>Source plant</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>5, 3', 5'-trihydroxy-6, 7, 4'-trimethoxyflavone</td>
<td><img src="#" alt="Chemical Structure" /></td>
<td><em>Murraya paniculata</em></td>
<td>Kinoshita and Firman (1996)</td>
</tr>
<tr>
<td>2.</td>
<td>5, 7, 3', 4', 5'-pentamethoxyflavone, 5, 6, 7, 3', 4', 5'-hexamethoxyflavone, 3, 5, 7, 8, 3', 4', 5'-heptamethoxyflavone, 5, 7, 8, 3', 4', 5'-hexamethoxyflavone, 5-hydroxy-3, 7, 8, 3', 4', 5'-hexamethoxyflavone, 8-hydroxy-3, 7, 8, 3', 4', 5'-hexamethoxyflavone.</td>
<td><img src="#" alt="Chemical Structure" /></td>
<td><em>Murraya paniculata</em></td>
<td>Ferracin <em>et al.</em> (1998)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><img src="#" alt="Chemical Structure" /></td>
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<td></td>
<td></td>
<td><img src="#" alt="Chemical Structure" /></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Daidzen-R'<R, R': OH, R4: H
Genistein-R'<R, R': OH, R4:H
6. Miscellaneous

Desoky (1995) reported five novel phytosterols from the cyclohexane extract of the leaves of *M. exotica*. Based on the physical, chemical, and spectral analysis, the structures of the isolated compounds were elucidated as (23S)-23-ethyl-24-methyl-cycloart-24(24)-en-3ß-ol, 3ß-methoxy-(23S)-23-ethyl-24-methyl-cycloart-24(24)-en-3ß-ol, (23S)-23-ethyl-24-methyl-cycloart-24(24ß)-3ß-y1 acetate, (23ßO)-23-isopropyl-24-methyl-cycloart-25-en-3ß-ol, (23ßO)-23-isopropyl-24-methyl-cycloart-25-en-3ß-y1 acetate. Mondal *et al.* (2001) reported a water extractable material from the cold water extract of the gum obtained from the immature fruits of *M. paniculata*, which was found to contain 85.7% polysaccharide and 2.9% protein. The polysaccharide was found to be a heterogalactan and extensively branched. It consisted of 1, 3, 6-linked ß-D-galactopyranosyl units, terminal ß-D-galactopyranosyl units, and terminal α-D-glucopyranosyl 1, 4-ß-D-galactopyranosyl units. Small amounts of 4-O-methylglucuronic acid residues and arabinose were also present. Raju *et al.* (2007) investigated the carotenoid composition and vitamin A activity of the medicinally important green leafy vegetables (GLVs). The total xanthophylls content in *M. koenigii* was found to be 38.43 mg/100 g dry weight whereas the total provitamin A carotenoids were found to be 11.82 mg/100 g dry weight. *M. koenigii* was found to contain 54.12% lutein, 5.71% α-carotene and 17.81% β-carotene in the total carotenoids.

The antioxidant capacities of 133 Indian medicinal plants were assessed by using ABTS, DPPH and FRAP assays (Surveswaran *et al.*, 2007). The leaves of *M. exotica* L. showed 10.33 mM/100 g dry weight in ABTS assay, 8.57 mM/100 g dry weight in DPPH assay, 1.80 µM/g dry weight in FRAP assay. Ningappa *et al.* (2008) evaluated the different extracts of *M. koenigii* L. for their antioxidant and free radical scavenging properties. The highest antioxidant and free radical scavenging activity was shown by the alcohol: water (1:1) extract. The extract inhibited lipid peroxidation by 76% at 50 μg/ml, scavenged 93% of superoxides at 200 μg/3 ml and scavenged approximately 90% of hydroxyl and 1, 1-diphenyl-2-picrylhydrazyl radicals. The extract was also found to reduce cytochrome c and ferric ion levels, chelated ferrous ions and inhibited ferrous sulphate: ascorbate-induced fragmentation and sugar oxidation of DNA. Youwei *et al.* (2008) investigated the free radical scavenging activities of the crude extracts from sixty-nine kinds of fresh flowers using various assays. The scavenging activity of the extracts of *M. paniculata* was found to be 3.440% on DPPH radicals, 14.313% on hydroxyl radicals, and 80.090% on superoxide radicals. The polyphenolic content in the flowers of *M. paniculata* was found to be 0.531 mg CE/g.

The curry leaf is a source of flavonols with strong antioxidant activity (Singh *et al.*, 2011). The extraction solvent can affect the flavonol profile and the antioxidant activity of the extracts. They characterised the flavonol profile of curry leaf extracted with different solvents and the relative antioxidant capacity of the extracts by quantifying phenolic constituents. 10 flavonols: myricetin-3-galactoside, quercetin-3-diglucoside, quercetin-O-pentohexoside, quercetin-3-O-rutinoside, quercetin-3-glucoside, quercetin-3-acetylhexoside, quercetin-Oxypentoside, kaempferol-O-glucoside, kaempferol-aglycoside, and quercetin aglycone were detected by HPLC-DAD technique. The relative...
antioxidant capacity of curry leaf flavonols prepared using 100% acetone, 100% MeOH, 80% MeOH, and 100% EtOH was compared by the TBARS assay. A significant antioxidant activity at 5.0 lg/g flavonols was shown by the curry leaf extracts. The leaves of *M. koenigii* serve as a source of new antimicrobial, antioxidant, and cytotoxic compounds (Kusuma et al., 2011). The biological activities of Indonesian medicinal (*Murraya koenigii, Syzygium polyanthum, and Zingiber purpurea*) plants were investigated. The disc diffusion method, 1, 1-diphenyl-2-picrylhydrazyl radical scavenging assay and brine shrimp lethality test was used to test antimicrobial activity, antioxidant activity and cytotoxicity. In comparison to the standard drugs, *Murraya koenigii* leaf extract showed 0.38-1.25 activity index (AI) in the test organism. The presence of carbohydrate, tannin, alkaloid, steroid, triterpenoid, and flavonoid in the extracts of *M. koenigii* leaves and twigs was revealed by the phytochemical analysis.

Gupta and Prakash (2009) studied the antioxidant activity of Indian green leafy vegetables (GLVs), using various antioxidative assays. *M. koenigii* vegetables showed the strongest radical scavenging activity as compared to the other GLVs (83.441%). Shihabudeen and Priscilla (2010) investigated the antimicrobial activity of the selected Indian folk medicinal plants including *M. koenigii*. The methanolic extract of the plant was investigated for the antimicrobial activity. The extract was found to have potent antimicrobial activity against different pathogens. The phytochemical analysis was also carried which revealed the presence of coumarins, flavonoids, glycosides, phenols, tannins, saponins and steroids but absence of alkaloids.

Grover et al., 2003 evaluated the effects of oral feeding of 15% of powdered leaves of *M. koenigii* and 10% powder of seeds of *Brassica juncea* on serum glucose concentrations and kidney functions in streptozotocin (STZ; 100 mg/kg) diabetic rats for 60 days. The urine volume per day and urinary albumin levels were found to be significantly higher in diabetic controls (DC) as compared to normal controls (NC), after 60 days of STZ administration. Kaushik et al., 2011 investigated the mechanism of apoptosis induced by castor oil-induced diarrhoea and PGE2-induced enteropooling in rats was exhibited by kurrayam and koenimbive. The compounds were also found to produce a significant reduction in gastrointestinal motility in the charcoal meal test in Wister rats.

Verma et al. 2012 assessed the variations of essential oil yield and composition in two chemotypes (‘A’ and ‘B’) of *M. koenigii* in spring, summer, rainy, autumn and winter seasons under foot hill conditions of northern India. Significant variation in the composition of leaves was found due to seasonal changes. The monoterpane hydrocarbons were recorded higher during rainy season (88.3%); oxygenated monoterpenes (8.0%) and oxygenated sesquiterpenes (2.8%) during autumn, while sesquiterpene hydrocarbons reached their higher value in winter season (10.1%), in chemo-type ‘A’; whereas in chemo-type ‘B’, the amount monoterpane hydrocarbons (88.1%), sesquiterpene hydrocarbons (17.7%) and oxygenated sesquiterpenes (4.4%) were higher in summer, spring and autumn seasons, respectively. *M. koenigii* chemotype ‘A’ was found to be richer in essential oil and its major components were -pinene and sabinene, while the major component of the chemotype ‘B’ was -pine. The monoterpane hydrocarbons were the main constituent of the essential oils of both the chemotypes, but sesquiterpene hydrocarbons were also found to be present in good amount. In the spring and autumn seasons, the chemotype ‘A’ possessed higher essential oil and oxygenated terpenoids (C10 and C15), hence these seasons could be better for collection of their leaves. Similarly, chemotype ‘B’ contained higher percentage of oxygenated terpenoids in spring–summer or autumn seasons, so these could be collected either in these seasons.

Choudhury and Garg (2007) analyzed the minor and trace elements in curry leaves (*M. koenigii*), collected from 19 different Indian states. The variation in the elements was found to be dependent on geo-environmental factors and local soil characteristics. The leaves collected from the southern zone were found to be rich in K, Mg, Mn, Cl and P but depleted in Se, whereas the leaves from the northern zone were rich in Ca and those from the western zone were rich in Zn. Rao et al. 2011 investigated the chemical diversity of wild and cultivated *M. koenigii* leaf essential oils collected from ten Indian locations. The presence of ninety compounds (constituting 93.8–99.9% of the essential oils) was analyzed by GC and GC-MS. A-pinene (55.7%) and b-pinene (10.6%) were found to be present in the highest concentration in the essential oil of wild plants. They also identified tetradecanoic acid, hexadecanoic acid, piperitone, cada-1, 4-diene, 1, 10-di-epi-cubenol, c-eudesmol, a-muurolol, (Z, E)-farnesol and (Z, Z)-farnesol, in curry leaf essential oil for the first time.

Mandal et al., 2010 investigated the antidiarrhoeal activity of carbazole alkaloids of the seeds of *M. koenigii*. Three bioactive carbazole alkaloids, kurraym, koenimbive and koenine, were isolated from the n-hexane extract of the seeds. 1H-, 13C-, and 2D-NMR spectral data confirmed the structures of the compounds. Significant inhibitory activity against castor oil-induced diarrhoea and PGE2-induced enteropooling in rats was exhibited by kurrayam and koenimbive. The compounds were also found to produce a significant reduction in gastrointestinal motility in the charcoal meal test in Wister rats.

Roy et al., 2004 studied the mechanism of apoptosis induced by
mahanine (a carbazole alkaloid in *M. koenigii*) in human leukemia cells (HL-60). Mahanine (10 µM) was found to inhibit cell proliferation and induce of apoptosis in a time dependent manner. The changes in nuclear morphology, DNA fragmentation, activation of caspase like activities, poly (ADP-ribose) polymerase cleavage, release of cytochrome c into cytosol and stimulation of reactive oxygen species generation was observed in mahanine treated cells. Mahanine was found to activate various caspases such as caspase-3, -6, -8 and -9 (like) activities but not caspase-1 like activity. Mahanine was found to decrease the mitochondrial membrane potential of intact cells, and also disrupted cell cycle progression by increasing the number of cells in sub-diploid region, concomitantly with the decrease of cells in diploid phases, particularly at late hours of apoptosis, as revealed by flow cytometric analysis. Mahanine was found to down regulate the cell survival factors by activation of caspase-3 through mitochondrial dependent pathway. Pandit et al. 2012 evaluated the cytochrome P450 (CYP) inhibition potential of some Indian spices (*Capsicum annum*, *M. koenigii*, *Zingiber officinale*). The spice extracts were found to have higher inhibition potential, as revealed by fluorogenic assay. Among all the test substances, *C. annum* showed highest (IC$_{50}$=0.01 mg/ml) interaction potential for all the isozymes; whereas *Z. officinale* (IC$_{50}$=0.1 mg/ml) showed least interaction potential. *M. koenigii* leaf extract was found to show lower IC$_{50}$ than its bio active constituents mahanine and mahanimbine. Rout et al. 2010 used liquid CO$_2$ for the extraction of fresh flowers of *M. paniculata* Linn. The yield of floral extract was about 0.64%. Phenyl ethyl alcohol (3.3%), indole (1.2%), E-nerolidol (7.6%), benzyl benzoate (7.0%), phenyl ethyl benzoate (9.2%), manool (29.4%), etc. were the major components in the extract. GC and GC/MS was used to analyze the chemical composition of concrete, absolute, liquid CO$_2$ extract and liquid CO$_2$ fractions of concrete. Manool was found to be the major component.

7. CONCLUSION

The present article reviews the phytochemicals present in the genus *Murraya*. Of the 14 global species belonging to this genus, only three species i.e. *Murraya koenigii*, *Murraya paniculata* and *Murraya exotica* are found in India. The main categories of phytochemicals present in *Murraya* spp. include carbazole alkaloids, coumarins and flavonoid; which impart profuse pharmaceutical potential to the plants. The carbazole alkaloids have been reported to show antimutation, hypoglycaemic, hepatoprotective, antibacterial, anti-inflammatory, antioxidant, mosquitoicidal, anti-diabetic, antilipemic; whereas the coumarins show anti-tumor, anti-inflammatory, antinoceceptive, antimicrobial potential. The coumarins isolated from this genus have also been repoted to be used as antidote against snake venom. The leaves of *Murraya koenigii* can be utilized in Alzheimer’s disease and in dementia. The different parts of the plants of this genus help in scavenging free radicals and to control the oxidative stress.

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